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Advanced Information Displays for the 21st-Century Warrior (Reprint)

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The U.S. Army and the Defense Advanced Research Projects Agency (DARPA) have funded a number of programs which have as a goal the integration of flat panel display technologies into hand-held or helmet-mounted display systems. This report summarizes a number of such programs which are categorized as rotorcraft aviation, combat vehicle, dismounted infantry, medical, or some combination of the above. The test and evaluation of these various display systems also is presented.

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Advanced Information Displays for the 21st-Century Warrior

Most display integrators don't have to worry about how their systems will perform while someone is trying to destroy them, or how users can quickly obtain information from a display while under extreme psychological stress. The U.S. Army does.

by Henry J. Girolamo, Clarence E. Rash, and Thomas D. Gilroy

THE U.S. ARMY is no stranger to high-tech devices. From the use of hot-air balloons for observation of troop movements during the Civil War to advanced war-training simulators, the Army has always been on the leading edge of technology. This has never been more apparent than in the recent rapid advancements in electronic miniaturization. In the area of displays, the U.S. Army is moving aggressively to take advantage of new miniaturization technologies.

"Information is power" is a well-known adage, and there is no place where it is more important than on the battlefield. The more information available to generals and individual soldiers, the greater the likelihood of a successful mission. The problem is delivering the necessary information in a coherent and timely way.

The sources and types of information have proliferated on the modern battlefield. Satellites, airborne radar planes, ground and air

Avionics Division, Honeywell, Inc.

Fig. 1: Prototype of HMD for Miniature Flat Panel for Aviation program.

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Table 1: Comparison of Flat-Panel Technologies

Technology	Advantages	Disadvantages
Active-matrix LCD	Full color Superior image quality Video speed	Limits on viewing angles Requires backlighting
Passive-matrix LCD	Low cost Simple design	Reduced resolution Slow response
Electroluminescent	Very rugged High resolution Wide viewing angle Long life	Full color questionable Inefficient drive schemes
Plasma	Large sizes High luminance	Affected by electromagnetic fields
Field emission	High luminance High energy efficiency	Questionable reliability Higher voltages required
Light-emitting diode	Low cost	Lack of full color High power requirement
Vacuum fluorescent	High luminance Wide viewing angle	Limited resolution
Electrochromic	High contrast	Problems with addressing techniques Low pixel addressing speed

reconnaissance vehicles, laser rangefinders, and automatic target-recognition systems are only a few of these sources. In fact, information saturation is a real danger. Expert systems capable of sorting, integrating, and prioritizing this information may help solve this overload problem. But, regardless of how much or how little information is available, the information must be presented to the soldier. In other words, some type of display device is needed. Until recently, the display of choice has been the cathode-ray tube (CRT).

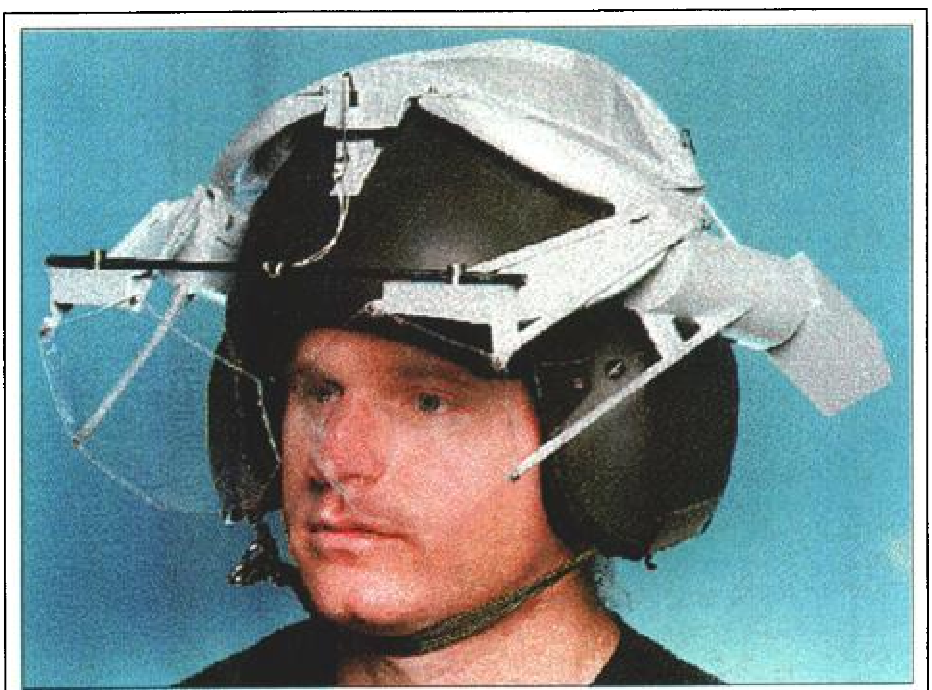
CRT displays offer dependability, low cost, and excellent image quality. But the CRT's inherent drawbacks of weight, size (primarily depth), heat generation, resolution capability, and power consumption are motivating the development of displays based on newer technologies.

FPD Technologies

CRT displays are based on a single technology: scanning electron beam. But flat-panel displays (FPDs) are based on a cornucopia of technologies, including liquid-crystal displays (LCDs), electroluminescent (EL) displays, plasma display panels (PDPs), field-emission displays (FEDs), and light-emitting diodes (LEDs) – all of which have distinct advantages and disadvantages (Table 1).

All display technologies can be classified as emissive (generating their own light) or non-emissive (requiring an auxiliary light source). EL, LED, and plasma displays are leading examples of emitters. LCDs, which act as shutters modulating the light passing through them, are the most common non-emissive type of display.

Despite their apparently recent emergence as competing display choices, these technologies are not new. The principle of electroluminescence was discovered in 1936, with the first patent for its application in a matrix display being filed in 1953. The first commercially viable LED display was introduced in 1968. The first designs for an active-matrix thin-film-transistor (TFT) LCD were proposed as early as 1968 at RCA Laboratories (now the David Sarnoff Research Center), Princeton, New Jersey, and Westinghouse Research Laboratories, Pittsburgh, Pennsylvania. But, as slow as the transition of these technologies into useful applications has been, one cannot look anywhere today and not see examples of



Aviation Applied Technology Directorate, Fort Eustis, Virginia.

Fig. 2: Advanced Visionics System HMD for CONDOR program.

Avionics Division, Honeywell, Inc.

Fig. 3: Combat Vehicle Crew (CVC) HMD.

FPDs. They are found in laptop computers, watches, hand-held televisions, electronic test instruments, calculators, and ovens - and the list goes on.

The most recent FPD applications area to emerge is the military. Weight, size, and power consumption are major concerns in the design of any device intended for military use, and displays using FP technologies are tailor-made for these three concerns. FPDs have been manufactured in sizes as small as three-quarters of an inch, measured diagonally.

Display subsystems using FPDs weigh much less than those using CRTs. This is especially significant for helmet-mounted displays (HMDs), in which miniature CRTs - with 1-in.-diameter screens - weigh 20 times as much as functionally equivalent miniature LCDs. While CRTs use operating voltages of 7000–35,000 V, FPDs use voltages of only 20–200 V. All of these advantages make FPDs perfect for integration into the 21st-century battlefield.

U.S. Army Programs

The integration of FPD technologies into U.S. Army programs has been rapid and wide-spread. Most of these programs can be classified by U.S. Army component, such as rotorcraft aviation, combat vehicles, medical, dismounted soldier, and maintenance. Other programs support multiple applications and are best classified as basic research and development (R&D) programs. Many of these programs are in support of integrated head-mounted display systems and are funded by the Defense Advanced Research Projects Agency (DARPA).

In 1991, DARPA established an HMD program with the goal of developing new display technologies that would overcome the technical challenges of CRTs and satisfy the strict operational requirements for HMDs. Two technologies - active-matrix electroluminescent (AMEL) and active-matrix liquid crystal (AMLCD) - were identified as the most promising display technologies. The DARPA HMD programs are directed by Dick Urban, Program Manager, DARPA, and Henry Girolamo of the U.S. Army Soldier Systems Command (SSCOM), Natick Research, Development, and Engineering Center in Natick, Massachusetts. Additional programs are funded fully or jointly by the Department of the Army (Table 2).

Rotorcraft Aviation Programs

Aviation is where the advantages of FPDs are most energetically sought. In the cockpit and, especially, on the aviator's head, space and weight are critical. Consequently, there are several aviation programs that are capitalizing on FPD technologies.

A major goal of the Miniature Flat Panel (MFP) HMD for Aviation program is investigating the use of miniature FPDs in an HMD for use in rotary-wing aircraft (Fig. 1). The program's goal is to build a prototype monochrome baseline HMD system utilizing a 1280 × 1024 AMEL image source. The MFP HMD is being developed by the Military Avionics Division of Honeywell, Inc., Minneapolis, Minnesota. The HMD will provide a 52° horizontal (H) × 30° vertical (V) field of view (FOV). The optical design is biocular with a 30° binocular overlap. The final system will consist of flight-worthy hardware and will be compatible with the U.S. Army's HGU-56/P aviator's helmet.

The program was launched in March 1994 and had a scheduled completion date of March 1997. In May 1995, a pre-baseline concept design using a 640 × 480-pixel LCD image source was completed and delivered to the U.S. Army for preliminary evaluation. A final prototype design based on a 1280 × 1024 AMEL image source has been developed, with testing scheduled for early 1997.

Another aviation application is the Aircrew Integrated Helmet System (AIHS) Comanche Compatibility program, which is an adjunct

Table 2: Overview of U.S. Army FPD Programs

Program	Application	Objective	Start date	End date
Miniature Flat Panel HMD for Aviation	Aviation	To investigate the concept of using FP technology in the development of an HMD for use in rotary-wing aircraft.	Mar 1994	Mar 1997
Aircrew Integrated Helmet System (AIHS) Comanche Compatibility	Aviation	To develop an HMD design using the HGU-56/P helmet shell that gives the Comanche developer an alternate system which capitalizes on recent display advancements.	Aug 1995	Dec 1999
Advanced Visionics System (AVS) for Covert Night/Day Operations for Rotorcraft (CONDOR)	Aviation	To develop a research HMD tool to use in investigating the impact of various display parameters on performance.	Jan 1994	Mar 1997
Combat Vehicle Crew (CVC) Head Mounted Display	Combat vehicle	To develop an HMD for providing battlefield information to tank commanders in a heads-out scenario.	Jul 1992	Jul 1995
Enhanced User Demonstration of CVC HMD	Combat vehicle	To integrate HMDs into combat vehicles and investigate human-factors issues.	Mar 1994	Aug 1997
Advanced Flat Panel HMD	Medical	To develop high-resolution (640 × 480 and 1280 × 1024) color and ultra-high-resolution (2560 × 2048) monochrome orthostereoscopic HMDs.	Jun 1994	Jul 1997
Hand-Held/Body-Worn Graphical Display System	Dismounted infantry	To develop a high-resolution portable display and computing platform for use in individual applications such as personal navigation.	Jun 1996	Jun 1998
Integrated Helmet Assembly Subsystem for the Generation 2 (GEN II) Soldier System and Force XXI Land Warrior	Dismounted infantry	To develop a helmet which provides an HMD, ballistic protection, integrated radio antenna, and integrated night-vision sensor.	Dec 1994 Evolved into LW & Force XXI LW	
Maintenance and Repair Support System (MARSS)	Maintenance	To develop an advanced lightweight body-mounted suite of electronics-integrated personal maintenance systems.	May 1995	May 1997
Advanced Microdisplays for Portable Systems	R&D/Multiple	To develop a series of color display systems with integrated drivers, control and interface logic, and novel low-power circuit techniques.	Jun 1996	Jun 1998
Micro-Opto Electro-Mechanical Systems (MOEMS) for Soldier-Based Systems	R&D/Multiple	To develop micro-opto electro-mechanical systems for head-mounted and hand-held display systems.	Jun 1996	Jun 1998
Advanced Technology for 2000 DPI HMDs	R&D/Multiple	To investigate extending resolution of AMEL and AMLCD displays to 2560 × 2048 in a 1-in. format using a 12-μm pixel pitch.	May 1994	Jul 1997
Combat Cueing (CBT-Q)	R&D/Multiple	To develop a portable tactical-information system that assists warfighters involved in small-unit operations.	Jun 1996	Dec 1998

program to the RAH-66 Comanche Helmet Integrated Display Sighting System (HIDSS). Managed by the Program Manager, Aircrew Integrated Systems, St. Louis, Missouri, the program's purpose is to develop an alternative HMD that capitalizes on the most recent advancements in displays and associated electronics. This parallel design must be compatible with the Army's AIHS, designated the HGU-56/P. This helmet meets the Army's long-term goal of fielding a single helmet usable in most, if not all, U.S. Army rotary-wing aircraft.

While not specifically requiring the use of FP technologies, the two contractors - Honeywell, Inc., and Kaiser Electronics, San Jose, California - are investigating alternative image sources and are expected to pursue designs incorporating miniature FPDs. The program's design criteria include wide FOV, head-tracking capability, biocular/monocular modes, and compatibility with Army image-intensification devices.

The first phase, which was initiated in August 1995, consisted of design-feasibility studies to analyze optimal image sources and optical-design approaches. The second phase,

U.S. Army Soldier Systems Command

Fig. 4: Demonstration of Advanced Flat Panel HMD during stereomicrosurgery at the U.S. Army Madigan Medical Center, Tacoma, Washington.

currently in progress, involves the construction and validation of a prototype design. A flight test of the final design is scheduled for late 1999.

A third aviation program is the Advanced Visionics System (AVS) program, which is the HMD subsystem being developed for the Covert Night/Day Operations for Rotorcraft (CONDOR) program. CONDOR, managed by the Aviation Applied Technology Directorate (AATD), Fort Eustis, Virginia, is a collaborative effort between the governments of the U.S. and the United Kingdom. CONDOR's goal is to couple an advanced avionics concept with an advanced flight-control system to improve rotorcraft mission effectiveness under adverse weather conditions during nap-of-the-earth flight, day or night. The AVS program is investigating the application of color displays, wide FOVs, stereo imagery, and other advanced imaging concepts to HMDs. The AVS HMD is intended for use in helicopters and ground-based simulators.

Just as important, the AVS HMD is a research tool that will enable researchers to investigate the impact of display parameters such as FOV, resolution, color, and percent overlap (Fig. 2). The AVS uses a subtractive-color AMLCD image source. Current design specifications are 120-fL peak luminance, 12:1 contrast ratio, 50° (V) × 60° (H) FOV per channel with selectable 20, 30, or 40° overlap, 1280 × 1024-pixel screen resolution, 15-mm-diameter exit pupil, and greater than 25-mm eye relief.[1] This program began in January 1994. Prototype testing and evaluation currently is in progress.

Combat-Vehicle Programs

Helicopters are not the only Army vehicles in which space and weight are limited. The Combat Vehicle Crew (CVC) Head Mounted Display program, which was completed in July 1995, developed a heads-out HMD (Fig. 3) that provides tank commanders with the vast amount of electronic battlefield information which previously was available only from the Commander's Independent Display located inside the turret. In addition, the CVC HMD allows tank commanders to track near-range threats, survey the proximal terrain, and avoid collisions with friendly vehicles and personnel.[2] The CVC HMD, developed by Honeywell, Inc., provides a 40° image and uses a 640 × 480 monochrome AMLCD developed by Kopin Corp., Taunton, Massachusetts. The HMD is a see-through binocular design with an approximate mass of 700 grams.

The Enhanced User Demonstration of the CVC HMD program has as a goal the integration of the CVC HMD into combat vehicles and the investigation of the associated human-factors issues. Specifically, the CVC HMD will be incorporated into the Army's M1A2 tank. If successful, tank commanders will have heads-up, eyes-out capability that will significantly increase situational awareness and mission effectiveness. Initiated in March 1994, the hands-on integration effort is being conducted at the U.S. Army Armor School, Fort Knox, Kentucky. The program has a scheduled ending date of August 1997.

Medical Program

With the recent increase in endoscopic surgical procedures for performing diagnostic and corrective surgery, there is a growing need to address the presentation of endoscopic medical imagery. Currently, this imagery is presented to the surgeon on CRT displays. The

Table 3: A Summary of Tests Conducted under USAARL's Display Program

Display Tests	Optical Tests	Visual-Performance Tests
Resolution	Field-of-view (FOV)	Visual field
Static MTF	Luminance transmittance	Static contrast sensitivity
Dynamic MTF	Spectral transmittance	Dynamic contrast sensitivity
Luminance range	Binocular overlap	Legibility
Luminance contrast	Exit-pupil size, shape, and location	Spatial acuity
Luminance uniformity	Focus range	Temporal battery
Chromaticity	Chromatic aberration	Vernier acuity
Gray levels	Spherical aberration	Dynamic target detection
Viewing angle	Astigmatic aberration	Peripheral target detection
Color contrast	Biocular/binocular disparities	Flicker detection
Spatiotemporal bandpass	Physical and optical eye relief	
Polarization	Refractive power	
Pixel geometry	Prismatic deviation	

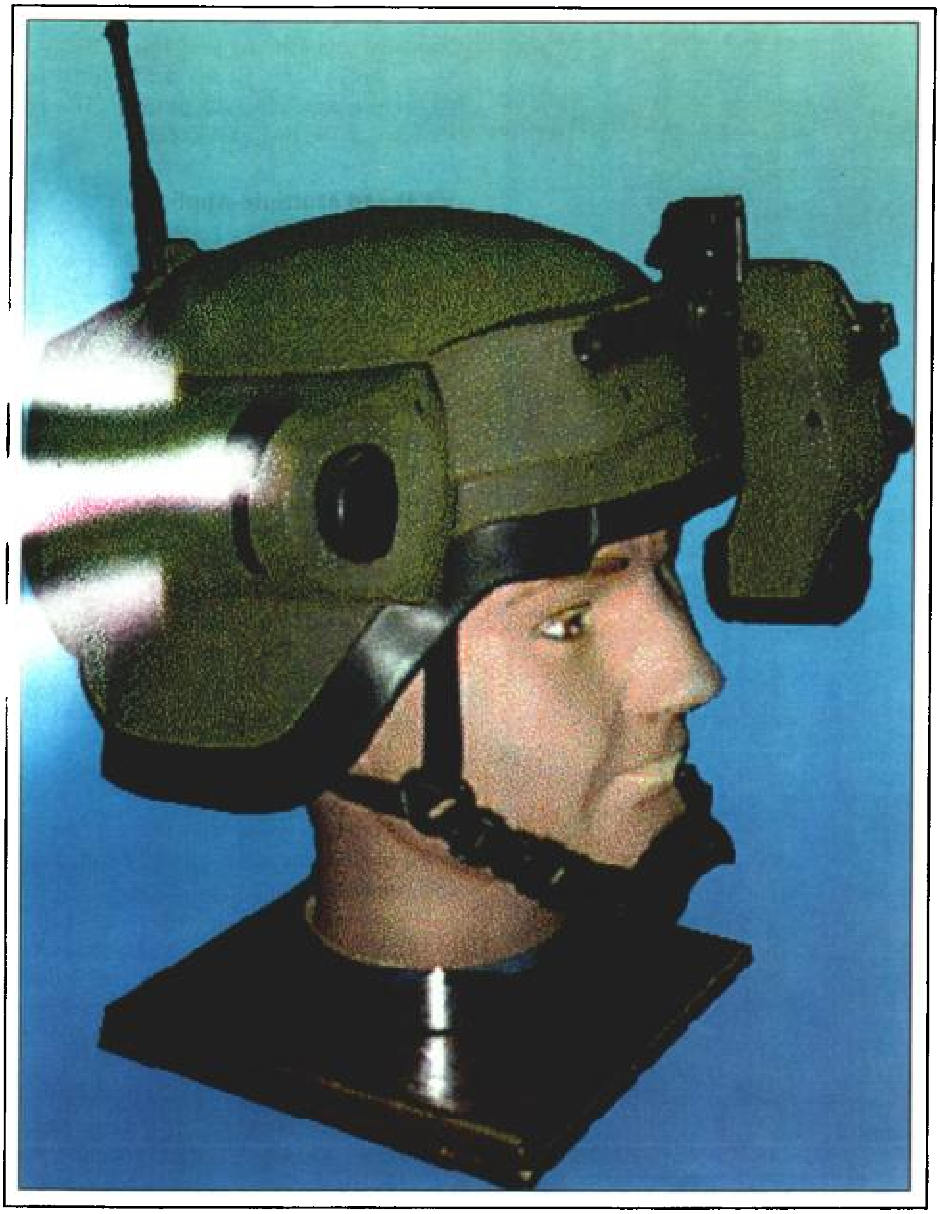


Fig. 5: The GEN II/Land Warrior Integrated Helmet Assembly Subsystem (IHAS) HMD for the dismounted soldier.

Advanced Flat Panel (AFP) HMD program attempts to integrate FPD and HMD technologies as a possible way of improving imagery presentation. This approach provides a number of ergometric and functional advantages over that of a CRT.[3] The AFP HMD will present high-quality color imagery comparable to that presently available on 21-in. CRTs, provide enhanced user comfort, provide improved eye-hand coordination, and be compatible with all individual and operating-room equipment and procedures. Under the AFP HMD program, two prototype systems are being fabricated, one using an AMEL image source and one an AMLCD. System specifications include 20° (H) × 16° (V) FOV, 1280 × 1024 (24-μm) pixel pitch, 15-mm exit pupil, less than 5% distortion, 32-mm eye relief, and a head-supported weight of less than 10 oz. Because surgeons rely heavily on color and color discrimination, a major goal of the AFP will be to provide as wide a color gamut as possible. Progress, to date, includes the design and fabrication of a stereoscopic surgical borescope HMD prototype (April 1996), design validation during several arthroscopic knee-surgery procedures at the U.S. Army Madigan Medical Center, Tacoma, Washington (August 1996) (Fig. 4), and the redesign and fabrication of an advanced prototype based on feedback from the validation surgical trials. Begun in June 1994 and originally intended to last for 30 months, the AFP program has been extended to June 1997 to accommodate the development of newer image sources. The system developer is Honeywell, Inc.

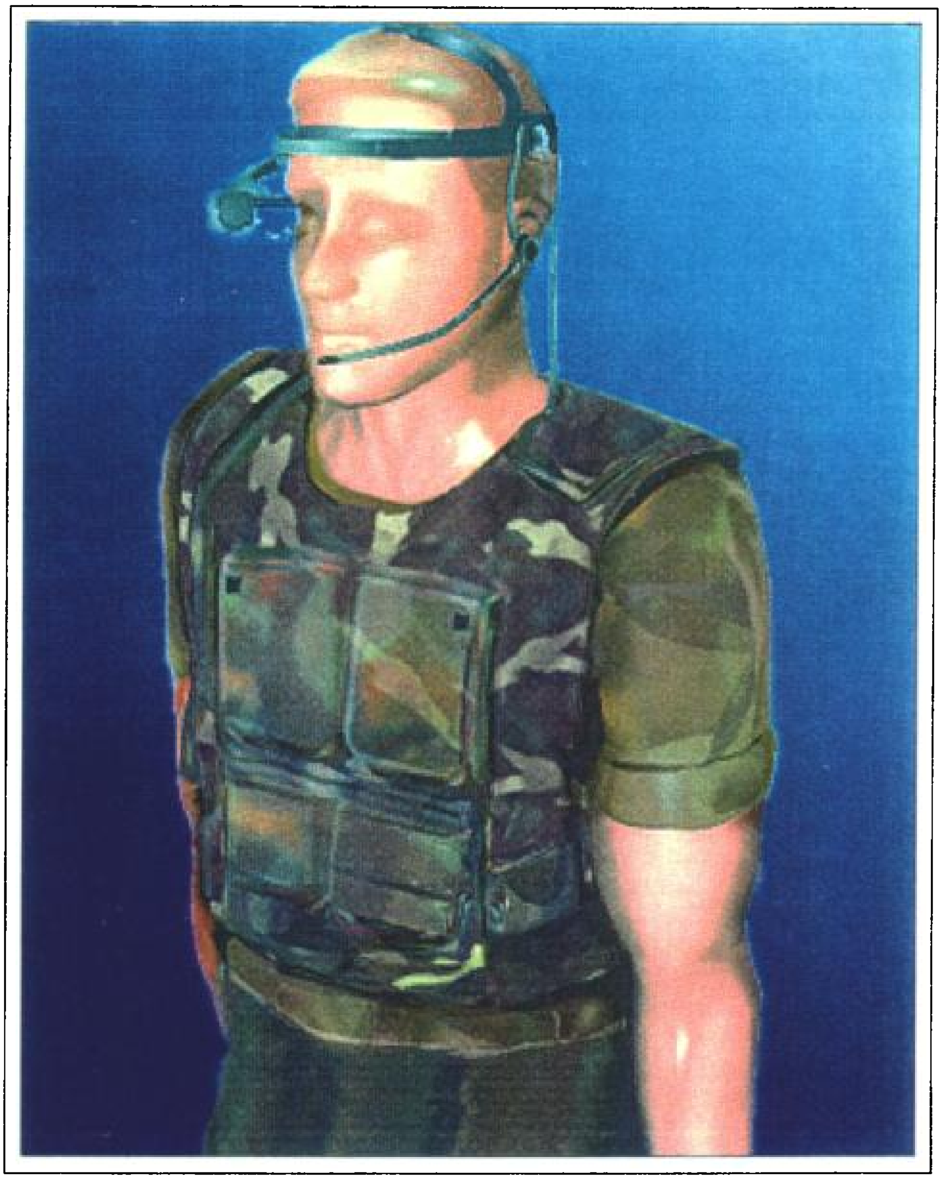
Dismounted-Soldier Program

In December 1994, the U.S. Army began a major program called the Generation 2 (GEN II) Soldier System. This program has evolved into the Force XXI Land Warrior (LW) program. The goal of this program is to enable dismounted infantry to operate more effectively and efficiently on the digital battlefield. LW's intent is to enhance soldier mobility, sustainability, survivability, and command/control capability. An LW subsystem, Honeywell's Integrated Helmet Assembly Subsystem (IHAS) will provide ballistic protection; advanced communications capability; an integrated night-vision sensor; an HMD for viewing computer data, sensor data, and imagery; and may integrate a head-orientation sensor.[4]

The IHAS HMD (Fig. 5) will use a 640 × 480 miniature FPD, with potential growth to a 1280 × 1024 display as part of the Force XXI technology insertion. An added feature is the incorporation of an automatic brightness function to adjust for background-illumination levels. The IHAS is expected to be a monocular, see-around optical design that can be positioned over either eye. System parameters include a 40° (H) × 32.5° (V) FOV, a 14-mm exit pupil (12 mm off axis), and a 26-mm eye-relief distance. Initial deliveries of the LW system have been completed and field testing is currently under way. Program developers for GEN II and Force XXI LW are Hughes Defense Systems, El Segundo, California; Motorola, Scottsdale, Arizona; and Honeywell, Inc.

Maintenance Programs

As advanced-technology systems increase their presence on the front lines, the technical



McDonnell Douglas

Fig. 6: Artist's conception of the Maintenance and Repair Support System (MARSS).

data and the knowledge required to maintain them will also increase. The Maintenance and Repair Support System (MARSS) program's goal is to develop an advanced, lightweight, body-mounted suite of electronics-integrated personal maintenance systems. The planned result is an open-architecture system consisting of a wearable personal computer with object-oriented software that controls and integrates plug-in measurement instrumentation, diagnostic processes, interactive electronic technical manuals, and logistical databases for the soldier.

System input/output are achieved via a head-mounted microphone and an AMEL FPD. MARSS will have wireless local-area-network (LAN) interaction with the weapons-system data bus and with other members of the maintenance team, which will allow transmission of fault and diagnostic data. The system will also incorporate data storage of multimedia repair-and-replace instructions on removable data-storage cards. All electronics are packaged into a vest garment (Fig. 6) having a total weight of less than 12 lbs. The display uses a 640 × 480 AMEL image source. The MARSS program began in May 1995, with a scheduled completion date of May 1997. McDonnell Douglas, Huntsville, Alabama, is the prime contractor on this program. Honeywell, Inc., is the HMD developer.

R&D and Multiple-Application Programs

There are a number of programs that have as goals the development of display-related subsystems or the investigation of improvements such as pixel resolution or microelectro-optics. These goals can be considered basic or applied R&D and be leveraged against current and future programs.

The Advanced Micro Display for Portable Systems program is an effort to develop advanced micro – less than 1 in. – displays for use in portable hand-held display systems. This is a continuation of past developmental programs to explore miniaturization of electronic displays. The program plans to capitalize on the ability to integrate high-performance digital and analog circuity on a single CMOS substrate together with the highest spatial-resolution color-triad reflected-mode AMLCDs ever fabricated.

This program will attempt to extend the frontier of display technology by developing and demonstrating:

- An unprecedented level of portable micro-display systems-integration technology with an emphasis on application-specific single-chip devices that incorporate communications, computing, and display circuitry.
- A new generation of ultra-low-power active-matrix and LC drive electronics based on newly developed adiabatic charge-recovery logic techniques, new low-power bistable LC materials, new integrated illumination and drive techniques, and reflected-mode operation.
- A new generation of AMLCD manufacturing technology to rapidly fabricate application-specific low-cost micro-displays.

This 2-year program began in June 1996. The system developer is MicroDisplay Corporation, Richmond, California.

The Micro-Opto Electro-Mechanical Systems (MOEMS) for Soldier-Based Systems program is a research effort to develop micro-miniature photon-beam-scanning devices that can be used in head-mounted and hand-held display systems. MOEMS will greatly reduce the weight and size of displays, optical devices, and sensors. The display systems will have high resolution, light weight, low power requirements, and a revolutionary smaller image source. MOEMS have the capacity to be integrated into current soldier-worn eyeglasses and wristwatches. The 2-year program was awarded in June 1996. The system developer is MicroOptical Corporation, Boston, Massachusetts.

The goal of the Advanced Technology for 2000-dpi HMDs program is to extend high-resolution AMLCD and AMEL displays to 2560 × 2048 pixels in a 1-in. format using a 12-μm pitch. In this program, DARPA is funding a research effort to continue the development of these high-resolution displays based on single-crystal silicon (x-Si). The displays utilize x-Si monolithic scanner circuitry and are fabricated using standard foundry processing to attain high speed, high yield, and wafer-based integrated processing.[5]

The approach being taken is to design, build, and test a variety of pixel configurations in 256 × 256 arrays, evaluate process options, design the scanner and control circuits, and then insert the optimized 12-μm pixel into the full 2560 × 2048 AMEL and AMLC display arrays with 2000-dpi resolution. These displays will then be integrated into the various DARPA and U.S. Army HMD programs for demonstration. Additionally, color filters will be added to both the AMELs and AMLCDs to produce 1280 × 1024 color displays.

The 2560 × 2048 displays will be demonstrated first in the AFP HMD program. The 2000-dpi display development program began in May 1994. The technical efforts were planned to last for 36 months, with a final program completion date of July 1997. This program is a collaboration among Kopin Corporation, Planar Systems, AlliedSignal Aerospace, Massachusetts Institute of Technology, and the University of Colorado.

A final DARPA-funded program that has broad application is the Combat Cueing (CBT-Q) program. Its goal is to develop a portable tactical-information system that assists warfighters involved in small-unit operations. The CBT-Q system will detect an enemy transmitter and instantly provide the warfighter with the emitter's position. CBT-Q technology can support land, sea, and air operations. The CBT-Q concept consists of three portable sites - two scout sites and one base site. Geolocation using the three sites, combined with global-positioning-satellite data, can pinpoint an enemy position. HMD and FPD systems and technologies developed under other DARPA programs will be leveraged to serve as the primary mode for presenting this information. Initiated in June 1996, this program is expected to demonstrate a prototype system by December 1998. The system developer is Raytheon E-Systems, Falls Church, Virginia.

Test and Evaluation

The numerous programs described here show great promise and will greatly enhance the effectiveness of the 21st-century warrior. However, the advantages of FP technologies and their myriad applications, both commercial and military, must be placed in perspective. There is no such thing as a free lunch. Just as the excellent image quality of CRTs is balanced by the problems of weight, size, and power, FPDs have their own disadvantages.

One serious concern of the U.S. Army engineers and scientists responsible for characterizing display performance in military applications involves the interaction of the time constants associated with the various sensors and displays. The issue of image smearing, present in some CRT display environments, is believed to be an even bigger issue with several types of FPDs. Dynamic effects are only one of several areas of concern with these new displays. A list of the disadvantages of the various FPD technologies is presented in Table 1, but it must be noted that the flat-panel industry is extremely active in addressing these disadvantages. Indeed, while it is unlikely that all the disadvantages will be overcome, tremendous improvements in brightness and producibility have been made within the past year, and there is every reason to expect continued improvements.

However, with or without solutions to the remaining problems, it is necessary to evaluate display performance - especially as it pertains to user visual performance. So, in addition to the testing done by system developers, all displays built under the auspices of the various programs are subjected to a formal U.S. Army test-and-evaluation (T&E) program.

Historically, this T&E has been conducted at the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, which has over 25 years' experience in display research and evaluation. USAARL researchers have contributed to all major U.S. Army display programs, including the Integrated Helmet and Display Sighting System (IHADSS) used on the AH-64 Apache helicopter, the Aviator's Night Vision Imaging System (ANVIS), and the Helmet Integrated Display Sighting System (HIDSS) under development for the RAH-66 Comanche helicopter.

The USAARL display research and T&E program, under the direction of Clarence E. Rash, provides a solid foundation for both T&E and problem-solving for electro-optical display systems. It consists of an experienced team of physicists, engineers, and vision scientists. The program provides a comprehensive testing of display parameters, optical-system parameters (for HMD systems), and visual performance (Table 3).

In Conclusion

This review of major FPD programs most recently pursued by the U.S. Army provides strong evidence for the aggressiveness with which the Army is capitalizing on new and rapidly expanding display technologies. These displays provide the capability to place compact and lightweight display systems in the hands and on the heads of the modern soldier, whether he or she is on the ground, on the road, or in the air.

References

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